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, GAUTHIER, Forrest, P.
Maineville, OH 45039 (US)
, JOVIC, Dimitrije, L.
Cincinnati, OH 45242 (US)

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(71) Applicant: **Varis Corporation**
Mason, OH 45040 (US)

(74) Representative:
Howden, Christopher Andrew et al
FORRESTER & BOEHMERT
Franz-Joseph-Strasse 38
80801 München (DE)

(72) Inventors:

(54) **SYSTEM AND METHOD FOR SYNCHRONIZING CLOCK SOURCES DRIVING PIEZOELECTRIC CRYSTALS OF INK JET PRINTHEADS**

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**SUPPLEMENTARY
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EP 97 94 7451

| DOCUMENTS CONSIDERED TO BE RELEVANT | | | |
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| | | | TECHNICAL FIELDS SEARCHED (Int.Cl.6) B41J G06K H04N |
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| Place of search THE HAGUE | | Date of completion of the search 27 February 2001 | Examiner Papastefanou, E |
| CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document | | | |

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1. A method for synchronizing a plurality of piezoelectric crystals on a corresponding plurality of ink jet printheads comprising the steps of:
 - embedding a first clock signal in data;
 - communicating said data to each of said printheads;
 - deriving said first clock signal from said data by said printheads;
 - generating a second clock signal from said first clock signal by said printheads; and
 - driving corresponding piezoelectric crystals with said second clock signal.
2. The method of claim 1, wherein said plurality of printheads are coupled together in a daisy-chain configuration to form a printhead daisy-chain.
3. The method of claim 2, wherein said communicating step includes the steps of:
 - transmitting said data to a first one of said printheads in said printhead daisy-chain; and
 - receiving and retransmitting said data to a next one of said printheads in said printhead daisy-chain by said printheads, until said data is retransmitted to a last one of said printheads in said printhead daisy-chain.
4. The method of claim 3, wherein said second clock signal includes a phase and a frequency, and the method further comprises the step of:
 - adjusting said phase of said second clock signal, by said printheads, according to a time it takes for said data to be received by said printheads.
5. The method of claim 3, wherein a printer controller is coupled to a first one of said printheads in said printhead daisy-chain and said printer controller performs said embedding and transmitting steps.
6. The method of claim 4, wherein said printer controller is coupled to

said last one of said printheads in said printhead daisy-chain, and said communicating step includes the step of retransmitting said data from said last printhead in said printhead daisy-chain to said printer controller.

7. The method of claim 6, wherein said plurality of printheads are coupled together with serial datalinks, said printer controller is coupled to said first printhead on said printhead daisy-chain with a serial datalink, and said printer controller is coupled to said last printhead on said printhead daisy-chain with a serial datalink.

8. The method of claim 7, wherein said serial datalinks are fiber optic links.

9. The method of claim 8, wherein:
said data is transmitted in said transmitting step using a self-clocking data transmission code; and
said data is transmitted in all of said retransmitting steps using said self-clocking data transmission code.

10. The method of claim 7, wherein said first clock signal is generated by a single clock source on said printer.

11. The method of claim 7, wherein:
said data is transmitted in said transmitting step using a self-clocking data transmission code; and
said data is transmitted in all of said retransmitting steps using said self-clocking data transmission code.

12. The method of claim 1, wherein said second clock signal includes a phase and a frequency, and the method further comprises the step of:
adjusting said phase of said second clock signal, by said printheads,

according to a time it takes for said data to be communicated to said printheads.

13. The method of claim 1, wherein said generating step includes the steps of:

clocking a free running counter with said first clock signal, said counter having a count output;

translating said count output to a voltage amplitude level value corresponding to a respective point along a sinusoidal voltage signal period; and

converting said voltage amplitude level value to an analog voltage.

14. The method of claim 13, further comprising the step of initializing said counters with a preload value, said preload value being defined according to a time it takes for said data to be communicated to said printheads.

15. The method of claim 13, further comprising the step of amplifying said analog voltage.

16. The method of claim 1, wherein said plurality of printheads are coupled to a printer controller in a star configuration, where said printer controller is at a hub of said star configuration and is coupled to each of said printheads with individual data links.

17. A system for dispatching bitmap data to a plurality of printheads and for controlling said plurality of printheads, comprising:

a controller including a processing circuit for generating the bitmap data, an output port, and an input port;

a plurality of printhead communication circuits, each of said communication circuits including an input port, an output port, a bitmap data transfer circuit, and a piezoelectric clock generation circuit for generating a

piezoelectric clock source;

each of said input and output ports of said communication circuits being coupled together with said input and output port of said controller by a plurality of data links arranged in a daisy-chain configuration; and

each of said bitmap data transfer circuits being coupled to a corresponding one of the printheads to provide the bitmap data to said corresponding printhead, and each of said piezoelectric clock generation circuits being coupled to said corresponding printhead to provide a piezoelectric clock source for said corresponding printhead.

18. The system of claim 17, wherein:

said controller includes an encoder circuit, coupled to said output port of said controller, for encoding raw digital data and a first clock source into a data transmission code to be transmitted by said output port of said controller; and

each of said printhead communication circuits include a decoder circuit for decoding said data transmission code back into said raw digital data and into said first clock source, said decoder circuit having a data input coupled to said input port of said printhead communication circuit, a clock output coupled to said piezoelectric clock generation circuit for communicating said first clock source to said piezoelectric clock generation circuit, and a data output coupled to said bitmap data transfer circuit for communicating at least a portion of said raw digital data to said bitmap data transfer circuit;

wherein each of said piezoelectric clock sources are generated from said first clock source by said piezoelectric clock generation circuit.

19. The system of claim 18, wherein said plurality of data links are serial data links.

20. The system of claim 19, wherein said serial data links are fiber optic data links.

21. The system of claim 20, wherein each of said printhead communication circuits include a message processing circuit coupled to said data output of said decoder circuit, said message processing circuit being configured to monitor said raw data and to execute commands embedded in said raw data, whereby said controller controls the dispatching of the bitmap data to the plurality of ink jet printheads by embedding said bitmap data and said commands into said raw data.

22. The system of claim 21, wherein each of said printhead communication circuits include an encoder circuit coupled to said message processing circuit and coupled to said output port of said printhead communication circuit, wherein said message processing circuit is further configured to send said raw data to said encoder circuit of said printhead communication circuit which re-encodes said raw data into re-encoded data and which then sends said re-encoded data to said output port of said printhead communication circuit such that said re-encoded data is re-transmitted by said printhead communication circuit.

23. The system of claim 21, wherein each of said printhead communication circuits include at least one input discrete line coupled to said corresponding printhead and at least one output discrete line coupled to said corresponding printhead, and said message processing circuit is further configured to transmit a signal on said output discrete line or poll a signal on said input discrete line responsive to one of said commands.

24. The system of claim 18, wherein said piezoelectric clock generating circuit includes:

- a counter for generating a plurality of count values, having a clock input coupled to said clock output of said decoder circuit and a count value output;

- a memory circuit having an internal look-up table, a count value input

coupled to said count value output of said counter, and a voltage amplitude value output, said look-up table having a corresponding voltage amplitude value for each of said count values and said memory circuit being configured to set said voltage amplitude value output by consulting a count value received on said count value input with said look-up table; and

an digital-to-analog converter having a digital input coupled to said voltage amplitude value output and a piezoelectric clock source output.

25. The system of claim 24, wherein said piezoelectric clock generation circuit includes a frequency divider device coupled between said clock input of said counter and said clock output of said decoder circuit.

26. The system of claim 25, wherein said piezoelectric clock generation circuit includes a voltage amplifier coupled between said piezoelectric clock source output of said digital-to-analog converter and said corresponding ink jet printhead.

27. The system of claim 24, wherein
said piezoelectric clock generation circuit includes a preload register coupled to a preload input of said counter;
each of said printhead communication circuits include a message processing circuit coupled to said data output of said decoder circuit, said message processing circuit being configured to monitor said raw data and to execute commands embedded in said raw data;
said message processing circuit being further configured to update said preload register in the course of executing one of said commands; and
whereby said controller can control the phase of said piezoelectric source by embedding said commands into said raw data.

28. The system of claim 24, wherein
said printhead communication circuit includes a dispatch circuit and a

registration circuit;

said counter includes a digital clock output corresponding to a most significant bit of said count value output; and

said digital clock output is coupled to a clock input of said dispatch circuit and a clock input of said registration circuit;

whereby, operations of said registration circuit and said dispatch circuit will be synchronized with said piezoelectric clock source.

29. A system for dispatching bitmap data to a plurality of printheads and for controlling said plurality of printheads, comprising:

a controller including a processing circuit for generating the bitmap data, an output port, and an input port;

a plurality of printhead communication circuits, each of said communication circuits including an input port, an output port, a bitmap data transfer circuit, and a piezoelectric clock generation circuit for generating a piezoelectric clock source;

each of said input and output ports of said communication circuits being coupled to said input and output port of said controller; and

each of said bitmap data transfer circuits being coupled to a corresponding one of the printheads to provide the bitmap data to said corresponding printhead, and each of said piezoelectric clock generation circuits being coupled to said corresponding printhead to provide a piezoelectric clock source for said corresponding printhead.

30. The system of claim 29, wherein:

said controller includes an encoder circuit, coupled to said output port of said controller, for encoding raw digital data and a first clock source into a data transmission code to be transmitted by said output port of said controller; and

each of said printhead communication circuits include a decoder circuit for decoding said data transmission code back into said raw digital data and

into said first clock source, said decoder circuit having a data input coupled to said input port of said printhead communication circuit, a clock output coupled to said piezoelectric clock generation circuit for communicating said first clock source to said piezoelectric clock generation circuit, and a data output coupled to said bitmap data transfer circuit for communicating at least a portion of said raw digital data to said bitmap data transfer circuit;

wherein each of said piezoelectric clock sources are generated from said first clock source by said piezoelectric clock generation circuit.

31. The system of claim 30, wherein each of said input and output ports of said communication circuits are coupled together with said input and output port of said controller by a plurality of data links arranged in a daisy-chain configuration.

32. The system of claim 30, wherein each of said input and output ports of said communication circuits are coupled to said input and output port of said controller by a plurality of data links arranged in a star configuration, wherein said printer controller is at a hub of said star configuration.

33. A high-speed ink jet printing system comprising:

a printer controller including a processing circuit for generating rasterized bitmap data, a clock source, an output port, an input port, and an encoder circuit for embedding said clock source in data transmitted by said output port of said printer controller;

a plurality of ink jet printheads, each of said printheads being positioned in a staggered formation along a web, and each of said printheads having a nozzle array for transferring a corresponding swath of an image to said web; and

a plurality of printhead communication circuits, each of said communication circuits including an input port, an output port, a bitmap data transfer circuit, a decoder circuit for extracting said clock source from data

received on said input port of said communication circuit, and a piezoelectric clock generation circuit for generating a piezoelectric clock source from said clock source extracted from said data received on said input port of said communication circuit;

each of said input and output ports of said communication circuits being coupled together with said input and output ports of said controller by a plurality of data links arranged in a daisy-chain configuration; and

each of said bitmap data transfer circuits being coupled to a corresponding one of the printheads to provide the bitmap data to said corresponding printhead, and each of said piezoelectric clock generation circuits being coupled to said corresponding printhead to provide a piezoelectric clock source for said corresponding printhead;

whereby, all the piezoelectric clock sources will be synchronized with said clock source, thus facilitating electronic stitching of said image swaths to a sub-pixel level.

34. A method for synchronizing a plurality of pixel generation mechanisms on a corresponding plurality of print engines comprising the steps of:

- providing a plurality of print engines, each of the print engines including a pixel deposition mechanism, the pixel deposition mechanism having a pixel deposition clock signal for providing a pixel deposition frequency for the pixel deposition mechanism;
- embedding a first clock signal in data so as to produce a combined data and clock signal;
- communicating the combined data and clock signal to each of the print engines;
- deriving the first clock signal from the combined data and clock signal by each of the print engines; and
- generating the pixel deposition clock signal for each of the plurality of pixel deposition mechanisms by each of the print engines;

whereby the pixel deposition frequency of each of the plurality of pixel deposition mechanism are generated from the first clock signal.

35. The method of claim 34, wherein the plurality of print engines are coupled together in a daisy-chain configuration to form a print engine daisy-chain and wherein the communicating step includes the steps of:

- transmitting the combined data and clock signal to a first one of the print engines in the print engine daisy chain; and
- receiving and retransmitting the combined data and clock signal to a next one of the print engines in the print engine daisy-chain by the print engines until the combined data and clock signal is retransmitted to a last one of the print engines in the print engine daisy chain.

36. The method of claim 35, wherein the pixel deposition clock signal includes a phase and a frequency, and the method further comprises the step of:

- adjusting the phase of the pixel deposition clock signal, by the print engines, according to an amount of time for the combined data and clock signal to be received by the print engines.

37. The method of claim 35, wherein a printer controller is coupled to a first one of the print engines in the print engine daisy-chain and the printer controller performs the embedding and transmitting steps.

38. The method of claim 37, wherein the printer controller is coupled to the last one of the print engines in the print engine daisy chain, and the communicating step includes the step of retransmitting the combined data and clock signal from the last print engine in the print engine daisy chain to the printer controller.

39. The method of claim 38, wherein:

- the plurality of print engines are coupled together with fiber optic links;
- the printer controller is coupled to the first print engine on the print engine daisy-chain with a fiber optic link;
- the printer controller is coupled to the last print engine on the print engine daisy-

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chain with a fiber optic link;

the transmitting and retransmitting steps are performed over the fiber optic links;

the combined data and clock signal is transmitted in the transmitting step using a self-clocking data transmission code; and

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the combined data and clock signal is transmitted in all of the retransmitting steps using the self-clocking data transmission code.

40. A method for generating a stroke frequency signal on a plurality of ink jet printheads arranged along a moving web, comprising the steps of:
embedding a web velocity signal indicative of web velocity in data;
communicating said data to each of said printheads;
deriving said web velocity signal from said data by said printheads; and
generating a stroke frequency signal from said web velocity signal by said printheads.

41. The method of claim 40, wherein said generating step includes the steps of:
clocking a counter with a first clock signal by said printheads, said counter having a terminal count output;
calculating a preload value from said web velocity signal; and
initializing counter with said preload value;
whereby, said terminal count output will be the stroke frequency signal.

42. The method of claim 41, further comprising the steps of:
embedding a second clock signal in said data;
deriving said second clock signal from said data by said printheads; and
generating said first clock signal from said second clock signal;
whereby said counters on each of said printheads are synchronized with said second clock signal and, in turn, with one another.

43. The method of claim 42, further comprising the steps of:
generating a piezoelectric clock source from said second clock signal by said printheads; and
each of said printheads driving a piezoelectric crystal on said printhead with said piezoelectric clock source;
whereby said stroke frequency signal is synchronized with said piezoelectric clock source on each of said printheads, thus facilitating electronic control and stitching of image swaths generated by said printheads.

44. The method of claim 40, wherein said plurality of printheads are coupled together in a daisy-chain configuration to form a printhead daisy-chain.

45. The method of claim 44, wherein said communicating step includes the steps of:
transmitting said data to a first one of said printheads in said printhead daisy-chain; and

receiving and retransmitting said data to a next one of said printheads in said printhead daisy-chain by said printheads, until said data is retransmitted to a last one of said printheads in said printhead daisy-chain.

46. The method of claim 45, wherein a printer controller is coupled to a first one of said printheads in said printhead daisy-chain and said printer controller performs said embedding and transmitting steps.

47. The method of claim 46, wherein said printer controller is coupled to said last one of said printheads in said printhead daisy-chain, and said communicating step includes the step of retransmitting said data from said last printhead in said printhead daisy-chain to said printer controller.

48. The method of claim 47, wherein said plurality of printheads are coupled together with serial datalinks, said printer controller is coupled to said first printhead on said printhead daisy-chain with a serial datalink, and said printer controller is coupled to said last printhead on said printhead daisy-chain with a serial datalink.

49. The method of claim 48, wherein said serial datalinks are fiber optic links.

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